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## OF
# THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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# THE JOURNAL

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## OF CANADA

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# THE ORBIT OF THE SPECTROSCOPIC BINARY 14 AURIGAE

BY W. E. HARPER

NO measures of this star ($\alpha$ = 5h 09m $\delta$ = +32° 35′) have been previously published. It was placed on our program last January on the suggestion of Professor Frost, director of the Yerkes Observatory, who noted it as "probably a spectroscopic binary." Shortly afterwards he sent us the velocities of their five plates, which showed a range of variation of 40 km, and its discovery as a spectroscopic binary is therefore due to the Yerkes Observatory.

The approximate period of the star had been obtained when the Yerkes results were received. This period of 3.78 days, modified to 3.7888 by the Yerkes results and additional plates of our own, suits all the observations except the first one taken at the Yerkes Observatory. Professor Frost, with his usual kindness in such matters, has re-measured this plate, which he states to be of good quality. The mean of their two measures, which differ very little, is still about 13 km too positive for our curve. Allowing for a possible systematic difference of 3 km between our observations, there is still a residual of 10 km. This is larger than

is natural to expect in a star of type A2, whose lines are much better than the average. A value of the period of 3.7898 days suits the Yerkes results much better, but our own not so well, which are probably best satisfied by a period of 3.7885 days. I have therefore compromised on the period, paying most attention to our own observations. Probably the period should be given only to the third decimal place, as the fourth is uncertain.

There is a suspicion, from the way the observations group themselves in some of the periods tested, that the spectrum of the component star is bright enough to influence the measures, causing the well known blend effect. As the range in the variation of the primary is barely over 40 km, it would be hopeless to expect to separate the component spectra with our single prism instrument. The star is of photographic magnitude 5.2, and is thus rather faint to permit the use of our three-prism spectrograph to advantage.

Thirty-seven plates of the star were obtained in 1915, and from these the elements have been determined. In the following table are given the principal lines, the number of times used, and the average residual for each from the mean of the plate.

WAVE-LENGTH OF LINES IN 14 AURIGÆ

| Wave Length | Number of times used | Residual | Wave Length | Number of times used | Residual |
|---|---|---|---|---|---|
| 4572·199 | 16 | + 0·6 | 4260·513 | 13 | - 1·7 |
| 4549·746 | 35 | + 0·2 | 4250·637 | 11 | + 3·6 |
| 4534·139 | 19 | - 1·2 | 4235·991 | 11 | - 0·6 |
| 4501·423 | 10 | + 0·4 | 4233·421 | 33 | - 0·3 |
| 4481·464 | 36 | - 0·9 | 4227·124 | 21 | + 1·2 |
| 4415·333 | 15 | - 0·8 | 4215·745 | 30 | + 0·9 |
| 4404·857 | 13 | - 0·3 | 4202·278 | 5 | - 6·3 |
| 4395·147 | 6 | - 0·5 | 4198·719 | 19 | + 3·0 |
| 4351·991 | 30 | + 1·0 | 4143 839 | 28 | - 0·1 |
| 4340·667 | 32 | + 1·5 | 4101·890 | 5 | - 0·6 |
| 4325·707 | 26 | + 0·6 | 4077·862 | 14 | + 0·1 |
| 4307·980 | 17 | + 0·4 | 4071·861 | 8 | - 0·3 |
| 4294·369 | 5 | + 0·7 | 4063·706 | 25 | - 1·8 |
| 4290·070 | 35 | + 1·2 | 4045·929 | 35 | - 0·8 |
| 4271·645 | 33 | - 2·1 | 4005·402 | 12 | - 0·9 |

YERKES OBSERVATIONS OF 14 AURIGÆ

| Date | Julian Date G.M.T. | Phase | Velocity | O-C |
|---|---|---|---|---|
| 1913, Oct. 2 | 2,420,043·864 | 2·726 | + 4·8 | + 12·8 |
| 1914, Feb. 20 | 184·567 | 3·236 | + 11 | + 3 |
| Mar. 13 | 205·542 | 1·478 | − 31 | 0 |
| Mar. 16 | 208·553 | ·701 | − 8 | + 2 |
| Mar. 23 | 215·605 | ·175 | + 10 | + 3 |

OTTAWA OBSERVATIONS OF 14 AURIGÆ

| Plate | Obs.* | Date | Julian Date G.M.T. | Phase | Velocity | Wt. | O − C |
|---|---|---|---|---|---|---|---|
| | | 1915 | | | | | |
| 6722 | C-P' | Jan. 20 | 2,420,518·730 | 2·185 | + 6·2 | 2·5 | − 0·8 |
| 6798 | H | Feb. 18 | 547·616 | 2·550 | − 14·4 | 3·4 | + 0·1 |
| 6808 | C | Feb. 19 | 548·657 | 3·591 | + 11·2 | 2·4 | − 0·3 |
| 6829 | H | Mar. 3 | 560·647 | 2·425 | + 1·8 | 3·1 | + 1·6 |
| 6837 | H | Mar. 4 | 561·642 | 1·420 | − 33·5 | 3·1 | − 3·7 |
| 6856 | H | Mar. 11 | 568·608 | ·809 | − 11·8 | 3·8 | + 1·7 |
| 6864 | Y | Mar. 14 | 571·600 | ·012 | + 9·6 | 3·0 | − 0·4 |
| 6868 | H | Mar. 15 | 572 557 | ·969 | − 19·7 | 4·6 | − 0·7 |
| 6874 | H | Mar. 18 | 575·547 | ·170 | + 13·1 | 3·4 | + 5·8 |
| 6886 | Y | Mar. 23 | 580·514 | 1·348 | − 26·8 | 3·2 | + 2·0 |
| 6891 | H | Mar. 27 | 584·524 | 1·569 | − 32·7 | 3·0 | − 1·3 |
| 6893 | H | Mar. 29 | 586·616 | 3·662 | + 13·6 | 2·9 | + 2·1 |
| 6899 | H | Apr. 1 | 589·519 | 2·776 | 0·0 | 2·9 | + 6·7 |
| 6906 | H | Apr. 7 | 595·582 | 1·261 | − 20·1 | 3·3 | + 6·9 |
| 6912 | H | Apr. 8 | 596·541 | 2·220 | − 29·0 | 3·3 | − 4·5 |
| 6924 | H | Apr. 14 | 602·592 | ·693 | − 7·8 | 3·4 | + 1·4 |
| 7192 | H | Sept. 1 | 742·885 | ·791 | − 14·0 | 3·3 | − 0·9 |
| 7198 | Y | Sept. 2 | 743·827 | 1·733 | − 35·7 | 2·4 | − 4·1 |
| 7219 | H | Sept. 8 | 749·862 | ·190 | + 3·8 | 2·8 | − 2·9 |
| 7225 | Y | Sept. 9 | 750·810 | 1·138 | − 27·5 | 4·0 | − 3·2 |
| 7247 | H | Sept. 14 | 755·865 | 2·405 | − 19·5 | 3·2 | − 0·6 |
| 7255 | C | Sept. 15 | 756·867 | 3·407 | + 6·1 | 3·0 | − 4·2 |
| 7276 | H-Y | Sept. 21 | 762·729 | 1·691 | − 30·3 | 2·7 | + 1·3 |
| 7277 | H | Sept. 21 | 762 782 | 1·744 | − 26·6 | 3·7 | + 5·0 |
| 7285 | C | Sept. 22 | 763·750 | 2 712 | − 11·9 | 0·8 | − 3·1 |
| 7286 | C | Sept. 22 | 763·799 | 2·761 | − 5·9 | 2·5 | + 0·9 |
| 7297 | H | Sept. 28 | 769 784 | 1·168 | − 26·4 | 3·7 | − 1·4 |
| 7306 | C | Sept. 29 | 770·850 | 2·234 | − 23·0 | 3 8 | + 0·8 |
| 7314 | Y | Sept. 30 | 771·774 | 3·158 | + 1·6 | 2·2 | − 3·8 |
| 7331 | H | Oct. 10 | 781·785 | 1·803 | − 33·7 | 3·5 | − 2·5 |
| 7332 | H | Oct. 10 | 781·832 | 1·850 | − 33·0 | 3·3 | − 2·4 |
| 7344 | C | Oct. 15 | 786·767 | 2·996 | + 0·8 | 4·0 | − 0·2 |
| 7361 | Y | Oct. 24 | 795·748 | ·611 | − 11·0 | 3·9 | − 4·1 |
| 7397 | C | Nov. 12 | 814·605 | ·524 | − 7·5 | 2·3 | − 4·0 |
| 7446 | C | Dec. 10 | 842·570 | 1·967 | − 28·7 | 3·6 | + 0·7 |
| 7449 | P | Dec. 11 | 843·698 | 3·095 | + 6·8 | 2·7 | + 3·0 |
| 7453 | P | Dec. 20 | 852·597 | ·607 | − 5·8 | 3·6 | + 0·7 |

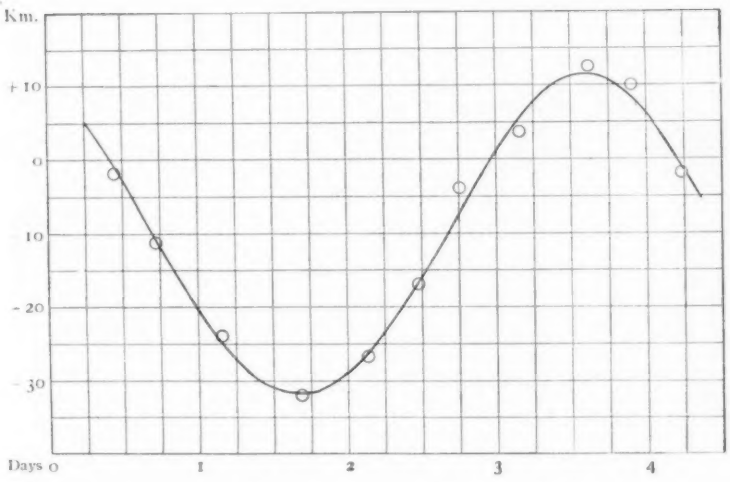
*C = Cannon. H = Harper. P = Plaskett. P' = Parker. Y = Young.

The preceding table gives the data of the measures. The phases are based on the final elements with small corrections for the earlier observations due to the light equation. The residuals are scaled from the curve representing the final elements, The probable error of a plate obtained from the last two columns is ± 2·0 km per second, which is lower than expected and quite satisfactory for the dispersion employed.

The observations were grouped into ten normal places and preliminary elements obtained in the usual way. Very small corrections resulted from the least squares solution but the value of $\Sigma pvv$ for the normal places was reduced from 22·1 to 16·2.

The following are the final elements:

| | | |
|---|---|---|
| $P$ = | 3·7888 days | |
| $e$ = | ·033 | ± ·022 |
| $\omega$ = | 19°·70 | ± 19°·70 |
| $K$ = | 21·56 km. | ± 0·50 km. |
| $\gamma$ = | − 10·74 km. | ± 0·34 km. |
| $T$ = | J.D. 2,420,802·715 | ± ·206 days |
| $a \sin i$ = | 1122600 km. | |




RADIAL VELOCITY CURVE OF 14 AURIGÆ

The graph represents the final elements with the observations as grouped.

DOMINION OBSERVATORY,
OTTAWA, CANADA,
January, 1916.

# THE SPECTROSCOPIC DETERMINATION OF THE SOLAR ROTATION AT OTTAWA

By J. S. Plaskett

(Abstract of paper published in *Astrophysical Journal*, December, 1915.)

THIS paper gives a summary of the values obtained for the solar rotation at Ottawa during the years 1911, 1912 and 1913. This investigation was undertaken in accordance with a co-operative plan arranged at the Mt. Wilson meeting of the International Union for Co-operation in Solar Research in 1910.

The instrumental equipment employed consists essentially of a horizontal coelostat telescope of 18 inches aperture and 80 feet focus, forming an image of the sun about 9 inches, (227 mm.), diameter on the face of a Littrow spectrograph of 23 feet focus. Reflecting prisms bring opposite limbs of the sun into juxtaposition on the slit and the Doppler displacements are measured on the photographed spectrum.

In the special region λ5600, at each of the latitudes 0°, 15°, 30°, 45°, 60°, 75°, 80°, 85°, there were selected and measured 19 plates made in 1911, 25 in 1912, and 20 in 1913. In the general region λ4250, at each of the latitudes 0°, 30°, 60°, there were selected and measured 24 plates made in 1911. At each of the latitudes 0°, 15°, 30°, 45°, 60°, 75°, there were 25 plates in 1912 and 17 in 1913 selected and measured. The total number of spectra measured was 834, of lines over 11,000, while the number of individual settings was upwards of 120,000.

The meaned results of these measures are given in Table I. and show a downward trend at the equator in 1913, as compared with 1912 and 1911. However, this lower value is not maintained at the higher altitudes and a better criterion is given by smoothing

TABLE I.

SUMMARY OF MEAN VALUES

| Year | 1911 | | 1912 | | 1913 | | Mean Values Reduced to Even Latitude |
|---|---|---|---|---|---|---|---|
| Region | λ5600 | λ4250 | λ5600 | λ4250 | λ5600 | λ4250 | |
| Number of Spectra | 19 | 24 | 25 | 25 | 20 | 17 | |
| Latitude | 0°2′ | 0°0′ | 0°0′ | 0°0′ | 0°0′ | 0°3′ | 0°0′ |
| Linear velocity | 2·017 | 2·012 | 2·014 | 2·005 | 1·989 | 1·971 | 2·003 |
| Angular velocity | 14°·32 | 14°·28 | 14°·30 | 14°·23 | 14°·11 | 14°·00 | 14°·20 |
| Latitude | 15°0′ | | 15°0′ | 14°54′ | 15°0′ | 14°54′ | 15°0′ |
| Linear velocity | 1·886 | | 1·874 | 1·914 | 1·891 | 1·876 | 1·889 |
| Angular velocity | 13°·86 | | 13°·78 | 14°·00 | 13°·90 | 13°·78 | 13°·88 |
| Latitude | 29°58′ | 29°59′ | 29°59′ | 29°52′ | 30°0′ | 29°50′ | 30°0′ |
| Linear velocity | 1·652 | 1·625 | 1·627 | 1·673 | 1·621 | 1·640 | 1·639 |
| Angular velocity | 13°·54 | 13°·32 | 13°·33 | 13°·70 | 13°·29 | 13°·42 | 13°·41 |
| Latitude | 44°52′ | | 44°58′ | 44°42′ | 45°0 | 44°45′ | 45°0′ |
| Linear velocity | 1·273 | | 1·225 | 1·272 | 1·231 | 1·244 | 1·246 |
| Angular velocity | 12°·75 | | 12°·29 | 12°·70 | 12°·36 | 12°·44 | 12°·51 |
| Latitude | 59°46′ | 59°53′ | 59°57′ | 59°29′ | 60°0′ | 59°36′ | 60°0′ |
| Linear velocity | 0·809 | ·788 | ·803 | ·832 | ·807 | ·828 | ·805 |
| Angular velocity | 11°·41 | 11°·15 | 11°·38 | 11°·63 | 11°·46 | 11°·62 | 11°·43 |
| Latitude | 74°28′ | | 74°54′ | 73°54′ | 74°58′ | 74°14′ | 75°0′ |
| Linear velocity | 0·417 | | ·368 | ·389 | ·369 | ·391 | ·373 |
| Angular velocity | 11°·05 | | 10°·03 | 9°·96 | 10°·10 | 10°·22 | 10°·23 |
| Latitude | 79°53′ | | 79°51′ | | 79°58′ | | 80°0′ |
| Linear velocity | 0·247 | | ·243 | | ·247 | | ·247 |
| Angular velocity | 9°·98 | | 9°·79 | | 10°·07 | | 10°·10 |
| Latitude | 84°47′ | | 84°42′ | | 84°55′ | | 85°0′ |
| Linear velocity | 0·131 | | ·132 | | ·129 | | ·127 |
| Angular velocity | 10°·23 | | 10°·15 | | 10°·34 | | 10°·34 |

out the irregularities by means of a formula of the Faye form, expressing the change of velocity with latitude.

Those employed have been :—

$$\text{Linear Velocity} \quad l' = (a - b \sin^2\phi) \cos\phi$$
$$\text{Angular Velocity} \quad \xi = a' - b' \sin^2\phi.$$

In these formulæ $\phi$ is the latitude, while the equatorial velocities are evidently $a$ and $a'$. The values of the constants in

Table II. show a decrease in velocity in 1913 as compared with 1911 and 1912 of slightly over one per cent.

TABLE II.

CONSTANTS OF FAYE FORMULÆ

| Year | Region | Linear | | Angular | |
|---|---|---|---|---|---|
| | | *a* | *b* | *a'* | *b'* |
| | | | | ° | ° |
| 1911 | λ 5600 | 2·012 | 0·500 | 14·28 | 3·55 |
| | λ 4250 | 2·016 | ·587 | 14·31 | 4·17 |
| | Both Regions | 2·012 | ·518 | 14·29 | 3·68 |
| 1912 | λ 5600 | 2·002 | ·558 | 14·21 | 3·96 |
| | λ 4250 | 2·022 | ·514 | 14·30 | 3·64 |
| | Both Regions | 2·012 | ·541 | 14·28 | 3·84 |
| 1913 | λ 5600 | 1·993 | ·518 | 14·14 | 3·68 |
| | λ 4250 | 1·980 | ·470 | 14·06 | 3·34 |
| | Both Regions | 1·988 | ·498 | 14·11 | 3·54 |
| 1911-12-13 | All Plates | 2·006 | 0·522 | 14·24 | 3·71 |

To see if this difference was due to a change in the habit of measurement, all the equator plates of the three years were re-measured, with the results given in Table III. The re-measured values of the 1911 and 1912 plates are, on the average, about 0.016 km. per sec. lower than the original, while the measures of the 1913 plates are practically unchanged.

TABLE III.

REMEASURES OF EQUATOR PLATES

| Year | λ 5600 Region | | | | λ 4250 Region | | | |
|---|---|---|---|---|---|---|---|---|
| | No. Plates | Original | Remeasure | Diff. | No. Plates | Original | Remeasure | Diff. |
| 1911 | 19 | 1·824 | 1·806 | 0·018 | 24 | 1·754 | 1·739 | 0·015 |
| 1912 | 25 | 1·848 | 1·835 | ·013 | 25 | 1·774 | 1·755 | ·019 |
| 1913 | 20 | 1·807 | 1·805 | 0·002 | 17 | 1·743 | 1·742 | 0·001 |

The application of such a correction brings the plates of these three years practically into agreement among themselves, and also

with a number of equator measures of 1910, and the results hence do not indicate any variation of the velocity of rotation.

The conclusions of the investigation may be summarized as follows:—

1. The value of the solar rotation determined at Ottawa can be expressed by the formulae

$$V = (2{\cdot}006 - 0{\cdot}522 \sin^2 \phi) \cos \phi$$
$$\xi = 14^{\circ}{\cdot}24 - 3^{\circ}{\cdot}71 \sin^2 \phi.$$

2. The values for the four years in which observations were obtained are in excellent agreement and the values of the constants of the foregoing formulae obtained from each of the six series are also in good agreement. The differences in the residuals, using the mean and separate values of the constants, are negligibly small, and the mean constants satisfactorily represent all the Ottawa observations.

3. So far as the interval covered by the Ottawa observations, 1910 to 1913, inclusive, is concerned the solar rotation is constant. The slight decrease obtained in 1913 is shown to be very probably due to a change in the habit of measurement.

4. The total range of mean velocity in each latitude is about 0.04 km per second. The most probable explanation of such differences is to ascribe them to local motions of the gases in the reversing layer.

5. The errors of measurement of the plates average about one-fourth the total errors as obtained by comparison of the plates, the average of the latter for a single plate being about 0.03 km per second.

6. Personal differences of measurement of different observers may be very much greater than the probable measurement error of either. The difference J.S.P.—R.E.D. averages +0.027 km per second and J.S.P.—H.H.P. +0.008 km per second.

7. The personal equation of measurement may change, the remeasurement of the equator plates of 1911 and 1912 giving values about 0.015 km per second lower.

8. In consideration of the possibility of these personal differences and changes, the value of the rotation may be uncertain to the extent of one or two hundredths of a kilometer. Such personal effects may explain part of the differences in the values obtained by different observers.

9. All the spectroscopic observations of the rotation of the reversing layer may be grouped into three sets of values, high, medium, and low. High values are obtained by Upsala, Edinburgh, and Mt. Wilson, and average at the equator 2.06 km per second. Medium values, obtained at Allegheny and Ottawa, run about 2.00 or 2.01 km. Low values, obtained at Cambridge and Kodaikanal, average about 1.9 km. The cause of such large differences in the values can most probably be assigned mainly to observational or instrumental errors and secondarily to personal differences of measurement.

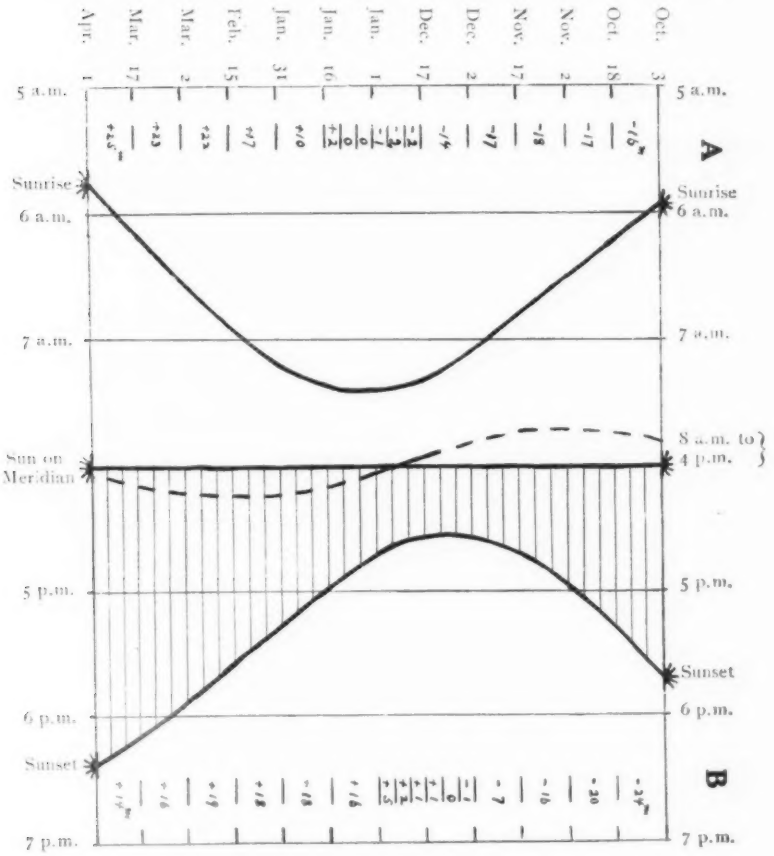
10. The large number of plates and measures made at Ottawa, much greater than at any other observatory, their close inter-agreement over four years' interval, and the care employed in the making and measurment of the plates entitle the Ottawa value to considerable weight.

11. No indication of any systematic differences of velocity for different lines or elements is given by the Ottawa measures.

# AN ANOMALY RESULTING FROM THE EQUATION OF TIME

By A. B. Turner

THE following article, written for the latitude of New York City (41° N), is in explanation of the fact that the day



increases much more slowly at the beginning of the year in the morning than it does in the afternoon. A similar anomaly, but in the other direction, is to be noted in December.

In the above diagram, the times of sunrise and sunset expressed in New York local mean time have been plotted at 15-day intervals, beginning with October 3 and ending April 1, 1915. Two smooth curves have been drawn through these points. For convenience of comparison, the two curves were brought closer together by omitting from the middle of the diagram the hours from 8 a.m. to 4 p.m. This brings 8 a.m. noon and 4 p.m. on the central line or meridian. The area horizontally shaded represents afternoon, the corresponding unshaded area the forenoon. The dotted curve was drawn to divide the interval from sunrise to sunset equally. This curve is the graphical representation of what is known in Astronomy as the "equation of time."

Following down the two solid curves, compare the lengths of the forenoon and afternoon. Applying the horizontal scale—one millimetre equals three minutes of time—to October 3, it is found that the forenoon is 22 minutes longer than the afternoon. Both diminish rapidly, the afternoon a little the faster, until November 2, when the forenoon is about 33 minutes longer than the afternoon. Then the forenoon diminishes more quickly than the afternoon until December 24, when they become equal. It is also noticeable that from November 27 to December 22—almost a month—the sun sets practically at the same time, 4:34 p.m., and consequently the afternoons are of constant length during this period. The curves come closest together on December 22 and we get the shortest interval from sunrise to sunset of the whole year. On December 9, however, two weeks before this shortest day, the afternoon begins to lengthen slowly, then quite rapidly; while on the other hand the forenoon is still shortening until January 8, when it, too, begins to lengthen out, slowly at first, then more rapidly. Between December 22 and January 16, the sun rises about the same time, 7:23 a.m. By February 11 the afternoon is 29 minutes longer than the forenoon. The latter over-

takes the afternoon about April 15. Between April 15 and June 14 the forenoon will be longer, while from June 14 to September 1 it will be shorter than the afternoon. (The complete diagram for the whole year is not shown, as the difference for the omitted portion is not so noticeable.) The columns A and B have been added to show the rate of change in the forenoon and afternoon for 15-day intervals; except around January 1 in A and December 17 in B, when the changes are very small and are given for 5-day intervals. For instance, from October 3 to 18 (column A), the forenoon diminished by 16 minutes and (column B) the afternoon by 24 minutes. Again, from March 17 to April 1 the forenoon increased by 25 minutes, the afternoon by 14 minutes.

The whole phenomenon that we have been discussing results from the fact that when the sun is on the meridian of an observer—central vertical line of the diagram—his local mean time does not indicate noon. The interval from the dotted curve to the meridian expressed in minutes, when subtracted from 12, if this curve is to the left, and added to 12 if the curve is to the right of the central line, will give the time of the sun on the meridian. For instance, on November 2 the sun was on the meridian about 16⅓ minutes before 12; on December24, at 12; on February 11, about 14½ minutes past 12. Twice this interval gives the difference between afternoon and forenoon and is *independent* of the observer's latitude. Leap year may vary the dates by a day and the time by a few seconds. The sunrise and sunset curves, however, do depend upon the observer's latitude both for their shape and position. For instance, in latitude 51°N the evenings show an increase of daylight during the month of January of 45 minutes while the mornings are only accelerated by 25 minutes.

THE COLLEGE OF THE CITY OF NEW YORK.

February 5, 1916.

## MEETINGS OF THE SOCIETY

### At Toronto

*February* 8, 1916.—A regular meeting was held in the rooms at 198 College Street, Dr. A. D. Watson in the chair.

The Secretary reported communications from three different gentlemen desiring to purchase telescopes, from Secretaries of the different Centres regarding program arrangements, and from Dr. R. E. De Lury of Ottawa regarding aurorae and ultra-violet light.

Miss E. P. Hayward, Mr. F. S. Carrington, Mr. S. A. Hearle and Rev. A. C. Ridsdale, who were nominated at the last regular meeting, were elected members of the Society.

Prof. Chant referred briefly to the predictions for the next two weeks as given in the Handbook. The conjunction of Venus and Jupiter next Sunday, Feb. 13th, was announced to be a very beautiful occurrence for the amateur astronomer to view.

Mr. W. E. Harper, M.A., of Ottawa, was then called upon to give the paper for the evening on "Nebulae." He introduced the subject by referring to the discovery of the gaseous nature of nebulae by Huggins and the early belief that it was a group of stars and merely required more powerful instruments to resolve the group into its component parts. He then traced the growth of the knowledge of nebulae from the first to the present time, treating of their character, forms and shapes and stating that spiral forms were the most abundant.

On examination by the spectroscope, the nebulae showed discontinuous spectra, usually only a few lines being present,

indicating that the nebula was gaseous and at low pressure, whilst planetary nebulae gave a continuous spectra similar to the solar type stars and had therefore solid or liquid components. Attention was called by the lecturer to the number of stars apparent near nebulae of certain types and suggested that possibly nebulous matter in certain stages of its life had something to do with the apparent vacant places in the stellar system.

The velocity of nebulae as determined from recent research was then taken up. Stars were stated to have velocities of from 6 to 18 km per sec., and the A-type stars, or those supposed to be in the earlier stages of formation, were the ones of lower velocity. It was to be expected, if nebulae were in an earlier stage of existence, that they would show smaller velocities. Keeler, however, from an examination of 11 planetary nebulae, obtained velocities of 24 km per sec.; whilst Campbell from 92 nebulae obtained 40 km per sec. as an average. The irregular nebulae having the lower velocities. On analysis, these nebulae, as well as the stars, gave the apex of the sun's way in the same place in the heavens.

Some recent work on spiral nebulae indicate velocities of 600 km per sec. and the apex of the sun's way derived therefrom to be in an entirely different part of the heavens. This indicates that spiral nebulae are outside of the galactic system, and probably form separate stellar universes.

Nebulae also have rotating motion and in some cases with high velocities. Different parts of the nebulae not always revolving in the same direction or with the same velocity.

The lecture was profusely illustrated by slides made chiefly from Keeler's and Ritchey's negatives.

Prof. De Lury moved, seconded by Prof. Chant, that the thanks of the meeting be extended to the lecturer. Carried.

W. E. W. Jackson, *Rec.-Sec.*

### At Ottawa

*January* 21, 1916.—The first meeting of the spring term of the Royal Astronomical Society of Canada was held in the

Geodetic Survey Building at 3 p.m. The following were duly elected members of the Society:

Dr. M. G. Larochelle, Civil Service Commission.

Mr. F. E. Buck, Experimental Farm.

Mr. T. L. Tanton, Geological Survey.

Mr. M. C. Jamieson, Dominion Observatory.

Dr. R. J. McDiarmid, of the staff of the Dominion Observatory, gave a lecture on "Photometric Measures of Eclipsing Variable Stars." After a brief description of the Princeton Observatory, in which the measures were carried on, the instrument used was described. The description was accompanied by a series of excellent lantern slides which gave a very good idea of the construction of the photometer. A sample set of observations was then shown. This gave an opportunity for Dr. McDiarmid to point out the method employed to eliminate the error due to the difference in length of path of the two sets of rays.

The resulting light curves for four sets of stars were then given and proved most interesting. In the first set the curve fell for about four hours and then rose as rapidly to a maximum. Here it remained until after a period of three days and twenty minutes it reached a second minimum. This was explained as the effect of the dark member of the system eclipsing the bright one. A second system had two maxima of different degrees, of different length, and with separating periods of full brightness which were unequal in length. The explanation given here was that there were two components of the same brightness, but one larger than the other. Hence one eclipse would be total and the other annular. This would account for the differences in degree and period of the two minima and also for the difference in length of the intervening period of maximum brightness. A third system had a curve showing two minima differing considerably in degree. In the portion between the principal minimum and the secondary minimum there was an increase of light up to the time of the secondary minimum. This was explained as being due to the two components being of different brightness. Hence as the

secondary eclipse was coming on, and the dark member was passing behind the bright one, more and more light would be reflected from the dark member until it actually began to go behind its brighter fellow. A fourth type had two minima of different degree, one being a sharp dip to a minimum and the other being flat when represented graphically, for about five hours. The explanation here was that the two components were elliptical and, like our sun, brighter in the centre than at the limb.

The explanations were accompanied by slides of diagrams which made the lecture very easy to follow. One striking feature of some of these diagrams was that the sun was drawn to scale on the same diagram as the stars, and was very much smaller than the latter.

The lecturer was tendered the thanks of the meeting for what was to all a very interesting and untechnical description of a generally little known phenomenon.

E. A. Hodgson, *Sec*

### At Peterborough

*February* 11, 1916.—An audience of upward two hundred gathered together early in the spacious hall adjoining St. Paul's Church.

The speaker of the evening, Mr. W. E. Harper, of Ottawa, was welcomed by the pastor. Mr. D. O'Connell, who was requested by the mayor to represent him, welcomed the speaker to the city.

Mr. Harper gave a very full and informative address on "Nebulae." He described the various forms of this wonderful aggregation of matter, explained where to find the more prominent systems.

He gradually unfolded the idea that, perhaps, the spiral nebulae were other entities, other "milky ways", and the universe as we see it is but a unit in systems so large that our system repre-

sents in it no more than does our solar system in our visible universe.

The large and appreciative audience followed the speaker with close and intelligent attention.

A vote of thanks was tendered to the speaker, to which he very aptly replied.

Some applications for membership were received and many enquiries about the date of the next meeting.

T. C. ELLIOT, *Sec.*

## NOTES FROM THE DOMINION OBSERVATORY

### ERRORS FROM BAD GUIDING OF A SPECTROGRAPH.

In his paper on "The Orbit of the Spectroscopic Binary *A* Bootis," (JOURNAL of the R.A.S.C., Jan., 1916,) Dr. Young has discussed, among other causes of high plate residuals, that of faulty guiding,—that is, the lack of uniform bisection of the star image by the slit. One would naturally suppose that there would be a much larger error among the different observers than among different plates taken by the same observer. An observer, continuously observing, with no longer intervals absent from the work than runs of bad weather necessitate, should guide always with the slit very near the same position of the star image. But different observers might easily guide with the slit slightly differently placed in regard to the star image. In order to ascertain whether there was any personal error in this regard, residuals were tabulated under the heads of the different observers, for fourteen stars whose orbits have been completed here. (Table I.)

In striking the mean residual of a plate secured by any observer, no star was included of which the observer had taken less than five plates.

From the table it will be seen that the mean residuals are very small,—in all cases negligible, except perhaps that of Cannon, whose mean is three-quarters of a kilometer positive.

It might be expected that the spectral type would come in as a factor in the residual from erratic bisecting of the image. The different types might give different relative positions for the

TABLE I.

| Star | P | H | Pa | V | C | Type |
|---|---|---|---|---|---|---|
| *d* Boötis | - 2·2 | - 0·3 | + 0·4 | | + 2·2 | F5 |
| *b* Persei | | + 1·2 | - 5·2 | | - 0·1 | A |
| *ξ* Persei | + 0·3 | - 2·5 | + 0·3 | | + 0·8 | Oe5B |
| *ζ* Andromedæ | | + 1·3 | - 1·9 | + 0·4 | - 1·3 | K |
| 139 Tauri | | + 0·4 | + 2·8 | - 1·2 | - 1·4 | A |
| *γ* Cor. Bor. | - 1·6 | + 0·0 | + 0·0 | | + 1·2 | F |
| 23 Cass. | - 1·5 | + 1·2 | | - 0·8 | + 3·0 | BS |
| 1149 Groom. | | - 0·6 | + 1·2 | + 0·9 | | A5 |
| 50 Draconis | | + 0·2 | | | | A |
| *ω* Cass. | | | - 2·4 | - 0·4 | + 0·5 | B9 |
| *φ* Persei | + 0·8 | - 0·2 | + 0·1 | | + 0·4 | Bp |
| 93 Leonis | - 1·6 | - 2·2 | + 2·6 | | + 0·3 | FS |
| *σ* Gem. | - 2·3 | - 1·1 | | | + 2·7 | K |
| *d* Tauri | + 3·1 | - 0·6 | | | | A2 |
| Means | - ·07 | - ·17 | - ·27 | - ·22 | + ·75 | |

NOTE:—P = Plaskett, H = Harper, Pa = Parker, V = Young, C = Cannon.

photographic and visual centres of the image. Table I. shows, however, that there is no systematic difference in regard to type.

As to the matter of the image getting displaced on the slit, while the observer is absent from the eyepiece for short intervals, the plates most likely to show this would be those taken at large hour angles. If the telescope be left to itself for a short time the image gradually drifts in declination and always in the same direction. Hence any considerable residual due to this cause should show itself readily. The hour angles of all the plates of several stars and the residuals of the plates were tabulated. But there was no positive result; there was no increase in the residual with increase in hour angle, nor was the residual always of the same sign.

From the above it must be said that, although the guiding error may, and undoubtedly does, contribute in the production of plate residuals larger than they should be, yet since nothing systematic has been found, there must be some other causes which are responsible for these residuals to a much greater extent than erratic guiding.

J. B. CANNON.

## REVIEW OF PUBLICATIONS

*Memoir on a Trans-Neptunian Planet.* By PERCIVAL LOWELL. Memoirs of the Lowell Observatory, Vol. I., No. 1; 105 pages, 9 plates, 1915.

Ever since the time of Adams and Leverrier it has been one of the dreams of astronomers to discover by analysis another planet beyond the orbit of Neptune; the present memoir is the most thorough and painstaking effort yet undertaken in this direction. Dr. Lowell is to be congratulated, not more on the result arrived at than on the manipulation of the analytical formulæ and the patience required for the immense computation involved.

The most obvious proceeding would be to utilize the deviations of Neptune from its computed orbit; but, as pointed out by the author, this method is rendered ineffective by the shortness of the time during which Neptune has been under observation, and the consequent possibility of satisfactorily representing its motion, even if perturbed, by the adoption of suitable elements. He therefore has recourse to the deviations of Uranus.

For the computation of the longitude of the unknown planet, the legitimate assumption is made that it travels in the same plane as Uranus; there remain, therefore, the following five elements to consider: —

$a'$, the mean distance (or $n'$, the mean motion)
$\epsilon'$, the mean longitude at the origin of the time
$e'$, the eccentricity
$\omega'$, the longitude of perihelion
$m'$, the mass.

It is necessary also to include in the solution corrections $\Delta n$, $\Delta\epsilon$, $\Delta e$ and $\Delta\omega$ to the corresponding elements of Uranus, making nine unknowns in all.

The general method of solution adopted was to assume values for $a'$ and $\epsilon'$ and to solve for the seven remaining quantities by the method of least squares; repetition of this process a sufficient number of times, with different values of $a'$ and $\epsilon'$, rendered it possible to find for all nine unknowns the values which made the sum of the squares of the residuals a minimum.

The observational data consisted of the deviations in longitude of the observed places of Uranus from those given by the theory of Gaillot; these were grouped into 37 observation equations; the total period covered was from 1690 to 1910. Several partial solutions were carried through, the number of observation equations utilized, and the number of perturbation terms taken account of, varying for the different solutions.

A preliminary partial solution (designated $[H_{14}]$ by the author) was first made, in which 24 observation equations, covering the period 1750 to 1903, were used. In this solution 25 perturbation terms, involving $e'$, $e$ and $e^2$, were taken account of; $a'$ was assumed as 47·5 units, and solutions were made for 20 values of $\epsilon'$ from 0° to 345°. Four minima of $\Sigma vv$, with respect to $\epsilon'$, were shown; two of these, however, were excluded by resulting negative values of $m'$. The main result of this partial solution was to locate $\epsilon'$ approximately, so that in the complete solution (repeated for other values of $a'$) it was not necessary to go all around the circle, but only to cover two parts of it.

The complete solution, designated $[H_{14}]_1$, was next carried through for values of $a'$ ranging from 40·5 to 51·25, a minimum of $\Sigma vv$ being shown between these limits; separate solutions were made from 24, 25, 27 and 37 observation equations respectively, all the results being fairly accordant.

Two other partial solutions were also made, one of them including 88 terms of the perturbative function, involving second order terms in $e'$. These were fairly accordant with $[H_{14}]_1$, and the complete solution was not carried through.

The two adopted solutions, corresponding to the double value of $\epsilon'$ mentioned above, are as follows:—

| | |
|---|---|
| $\epsilon' = 22°{\cdot}1$ | $\epsilon' = 205°{\cdot}0$ |
| $a' = 43{\cdot}0$ | $a' = 44{\cdot}7$ |
| $m' = 1{\cdot}00$ | $m' = 1{\cdot}14$ |
| $e' = {\cdot}202$ | $e' = {\cdot}195$ |
| $\omega' = 203°{\cdot}8$ | $\omega' = 19{\cdot}6$ |
| hel. long., July 0, 1914 $= 84°{\cdot}0$ | $262°{\cdot}8$. |

the unit of $m'$ being $\frac{1}{3000}$ the mass of the sun.

The following remarks by the author are of especial interest:

"There is indicated for the unknown a mass between Neptune's and the earth's; a visibility of the 12-13 magnitude according to albedo; and a disk of more than 1″ in diameter.

"From the analogy of the other members of the solar family, in which eccentricity and inclination are usually correlated, the inclination of its orbit to the plane of the ecliptic should be about 10°. This renders it more difficult to find.

"Investigations on the perturbations in latitude yielded no trustworthy results. This is probably because the eccentricity $e'$ as well as the planet's other elements enter as data into the latitude observation equations.

"The perturbative function is not discontinuous at the commensurability of period points, a fact hitherto in doubt."

With some of Dr. Lowell's other remarks, however, it is necessary to disagree. For example, there is no warrant in the theory of errors for the manipulation of figures on pages 102-103 by which, from a comparison of Gaillot's residuals with Lowell's, it is made to appear that the solutions have a probability of from 90 per cent. to 100 per cent. It may be added, indeed, that *no* direct comparison of residuals is of the slightest validity in such a case, unless account be taken of the conditions of the problem, and especially of the number of new unknowns introduced. As a matter of fact, the residuals from Gaillot's theory can not be used at all for such a comparison, without previous alteration, for the reason that they can be reduced by suitable alterations of

the elements of Uranus, without the assumption of the existence of any unknown disturbing force; this arises from the fact that the data used by Lowell are not identical with those from which Gaillot deduced his theory of Uranus. For example, in the solution $[H_{13}]$ (see p. 35), a solution for $\Delta n$, $\Delta\epsilon$, $\Delta e$ and $\Delta\omega$ alone reduces $\Sigma vv$ from 50″·4 to 45″·3; the latter is the quantity to be compared with Lowell's 14″·4.

In a previous issue of this JOURNAL* a criterion was deduced which is applicable to the present case. By a slight extension of the theorem there proved, a solution with $\mu'$ unknowns has a greater probabily than one with $\mu$ unknowns, if

$$\frac{\sqrt{\Sigma v'v'}}{n-\mu'} \text{ is less than } \frac{\sqrt{\Sigma vv}}{n-\mu},$$

$n$ being the number of observation equations. All of Lowell's solutions show a reduction of this quantity; in the case of the two solutions given above $n = 27$, $\mu = 4$, $\mu' = 9$, $\Sigma vv = 50''{\cdot}6$, $\Sigma v'v' = 15''{\cdot}5$ for the first, and 24″·1 for the second; the reduction in the criterion is, therefore, from ″·31 to ″·22 for the first solution, and from ″·31 to ″·27 for the second.

We conclude, then, that so far as the evidence goes, there is a probability in favor of the existence of a disturbing force such as would be exerted by a planet situated in the vicinity of either of the positions assigned by Dr. Lowell; further than that statement it would be perhaps unwise to go. It should be remarked also that the above criterion (and in fact the whole theory of least squares) is strictly applicable only when the observation equations have been weighted with due regard to their probable errors. That this has not been done in the present instance, as it was by Gaillot in developing the residuals used, is rather to be regretted, as a further element of uncertainty would thereby have been eliminated. It does not seem likely, however, that the result arrived at would have been materially different. Aside from details, it would appear that the theory of a trans-Neptunian planet will remain where Dr. Lowell has left it for a good many years to come, or until further data are forthcoming.

*Volume VII., p. 363.

R. M. STEWART.

## NOTES FROM THE METEOROLOGICAL SERVICE

### Summary Report of the Weather in Canada

FEBRUARY, 1916

*Temperature.*— The mean temperature of the month was considerably above the normal over the greater portion of the Prairie Provinces, while in British Columbia and from Lake Superior eastward it was from normal to 4° below. The largest positive departures, amounting to about 6°, occurred in Alberta and Northern Saskatchewan, while negative departures of 3° to 4° occurred in many parts of Ontario and Nova Scotia.

*Precipitation and Depth of Snow on the Ground.*— The precipitation was very generally in excess of the average in British Columbia and Alberta, and also in a district between the Georgian Bay and the Ottawa Valley, while in other parts of the Dominion it was either average or a little below. In Ontario, as in the Western Provinces, it was wholly in the form of snow. Although there was an unusually heavy snowfall on the coast of British Columbia during the early part of the month, by the 29th the snow had practically disappeared and only traces remained. At the close of the month, except in Southern Alberta where the ground was bare, the Western Provinces were snow-covered to a depth varying from three inches in Northern Alberta to twenty inches in some sections of Manitoba and Eastern Saskatchewan. In Southern and Western Ontario the snow was from four to twelve inches in depth, and this increased northward to four feet and over in the Algoma District. In Quebec the depth varied from twelve inches in the southern counties to three feet or more in the northern and eastern districts. Some localities in the Maritime Provinces had a covering of four to ten inches, while in others the ground was bare.

## Temperature for February, 1916

| Station | February | | Station | February | |
|---|---|---|---|---|---|
| | Highest | Lowest | | Highest | Lowest |
| *Yukon* | | | Huntsville | 39 | -28 |
| Dawson | 38 | -48 | Kenora | 44 | -30 |
| *British Columbia* | | | Kimmount | 37 | -35 |
| Atlin | 45 | -28 | Kingston | 41 | -16 |
| Agassiz | 62 | 15 | London | 41 | -16 |
| Barkerville | 48 | -20 | Lucknow | 33 | -14 |
| Kamloops | 50 | -20 | Markdale | 40 | -17 |
| New Westminster | 59 | 19 | North Gower | | |
| Prince Rupert | 61 | 14 | Oshawa | 38 | -16 |
| Vancouver | 56 | 21 | Ottawa | 42 | -18 |
| Victoria | 59 | 24 | Paris | 39 | -20 |
| *Western Provinces* | | | Parry Sound | 36 | -24 |
| Battleford | 50 | -33 | Peterboro' | 43 | -18 |
| Calgary | 66 | -20 | Port Arthur | 46 | -20 |
| Edmonton | 57 | -26 | Port Burwell | 44 | 16 |
| Medicine Hat | 57 | -28 | Port Dover | 40 | -14 |
| Minnedosa | 46 | -33 | Port Stanley | 38 | -17 |
| Moose Jaw | 52 | -32 | Queensborough | 45 | -23 |
| Oakbank | 42 | -34 | Ronville | 33 | -32 |
| Portage-la Prairie | | | Southampton | 39 | -19 |
| Prince Albert | 64 | -42 | Sundridge | | |
| Qu'Appelle | 46 | -30 | Stonecliffe | 35 | -30 |
| Regina | 40 | -31 | Stony Creek | 42 | -10 |
| Saskatoon | 43 | -32 | Toronto | 44 | - 9 |
| Souris | 39 | -34 | Uxbridge | 38 | -23 |
| Swift Current | 48 | -28 | Wallaceburg | 43 | - 1 |
| Winnipeg | 43 | -31 | Welland | 42 | - 7 |
| *Ontario* | | | White River | 40 | -46 |
| Agincourt | 39 | -17 | *Quebec* | | |
| Aurora | | | Brome | 40 | -34 |
| Bancroft | 46 | -27 | Father Point | 38 | -16 |
| Barrie | 38 | -18 | Montreal | 40 | -18 |
| Beatrice | 40 | -27 | Quebec | 37 | -23 |
| Berlin | 43 | -11 | Sherbrooke | 42 | -19 |
| Bloomfield | 45 | -17 | *Maritime Provinces* | | |
| Brantford | | | Charlottetown | 42 | -16 |
| Chapleau | 49 | -39 | Chatham | 44 | -20 |
| Chatham | 49 | 4 | Dalhousie | 38 | -18 |
| Clinton | 39 | -13 | Fredericton | 45 | -20 |
| Collingwood | 42 | -18 | Halifax | 48 | -14 |
| Cottam | 48 | - 2 | Moncton | 45 | -20 |
| Georgetown | 40 | -19 | St. John | 46 | -12 |
| Goderich | | | St. Stephen | | |
| Gravenhurst | 36 | -31 | Sussex | 45 | -25 |
| Grimsby | 43 | - 2 | Sydney | 46 | -24 |
| Guelph | 46 | -21 | Yarmouth | 48 | -10 |
| Haliburton | 37 | -31 | | | |

NOTE.—The Magnetic and Seismological Reports are held over until next issue.

## COMET NEWS

### TAYLOR'S COMET SPLITS IN TWO

As reported in the last issue, Barnard on February 9th observed that Taylor's comet had a double nucleus. At that time the two components were 9″·2 apart, and by the 26th this distance had increased to 12″·1, thus showing that the comet had broken into two parts which were slowly separating.

This recalls the remarkable case of Biela's comet. It was first seen in 1772, was re-discovered in 1805 and in 1826, and its period was found to be about 6 7 years. It was detected again towards the end of 1845, and in January, 1846, it was observed to be separated into two complete comets. At its next return in 1852 the two comets were much farther apart. Since then the comet has never been seen, but in its place is a meteoric swarm which produces the Andomedes, seen between November 20 and 27. (See the HANDBOOK, p. 50).

### ANOTHER COMET DISCOVERED

By means of photography Neujmin, at Simeis in the Crimea, discovered on February 24 a comet in R.A. $8^h\ 58^m\ 40^s$, Dec. + 16° 24′ (in Cancer). It is of about the 11th magnitude, is becoming fainter, and so has little interest for the amateur observer. The comet has a round nebulosity 2′ in diameter.

Two orbits have been calculated, one by Castro at the Observatorio Nacional, Santiago, Chile; the other by Miss

Young and Messrs. Jeffers and Pierce at the Student's Observatory, Berkeley, Cal., as follows :—

| | | Berkeley | Santiago |
|---|---|---|---|
| Time of perihelion passage | ($T$) | 1916, Mar. 11·22 | Mar. 3.21 G.M.T. |
| Perihelion minus node | ($\omega$) | 193° 44′ | 186° 27′ |
| Longitude of node | ($\Omega$) | 327° 39′ | 325° 18′ |
| Inclination | ($i$) | 10° 30′ | 17° 6′ |
| Perihelion distance | ($q$) | 1·334 | 1·581 |
| Eccentricity | ($e$) | 0·5547 | |
| Periodic line | ($P$) | 5·19 years. | Parabolic |

The following ephemeris accompanies the Berkeley elements :

EPHEMERIS

| G.M.T. | R.A. | Decl. | Light |
|---|---|---|---|
| 1916 | h m s | ° ′ | |
| March, 10·5 | 9 2 57 | + 8 24 | 1·11 |
| 14·5 | 9 6 0 | 6 25 | |
| 18·5 | 9 9 46 | 4 30 | |
| 22·5 | 9 14 18 | 2 40 | 0·93 |

C. A. CHANT.

## ASTRONOMICAL NOTES

THE TAIL OF HALLEY'S COMET.—Did the earth actually pass through the tail of Halley's Comet on May 21, 1910? M. E. Esclangon has made a careful discussion of the observations (*Annales de l'Observatoire de Bordeaux*, Vol. XV.), and his answer is "No." But near midnight on May 21 we were only 0·002 astronomical units outside the boundary of the tail—less than the distance which separates the moon from the earth. The boundary is here taken to correspond with the visibly luminous breadth of tail as observed before and after the approach, but if cometary matter extended beyond these limits the earth must have encountered it. Throughout a month about this period the tail was in the plane of the orbit, lagging about 45° behind the radius vector; had the deviation been only a little less we should have actually entered the tail.—*The Observatory*, No. 498.

FRENCH ASTRONOMERS AND THE WAR.—The French Academy of Sciences awards annually a number of prizes to authors of works of outstanding merit in various branches of science. It was decided that some of the prizes for the year 1915 should be awarded to scientists who had given their lives fighting in the service of their country for the rights of humanity. The names of two astronomers appear in this list:—That of M. Jean Merlin, who was appointed assistant at the Observatory of Paris in 1901, and became assistant-astronomer at the Observatory of Lyons in 1904. Besides astronomical work, he had also published papers on pure mathematics. Born at Rennes in 1876, he

fell in action at the Col. d'Arrozel, August 29, 1914. Also that of M. Rabioulle, formerly employed at the Paris Observatory from 1894, then as assistant-astronomer at Toulouse from 1911, and at Algiers from 1912. He was killed at Moulin-sous-Touvet, September 21, 1914. To these two astronomers jointly the Becquerel prize has been posthumously awarded by the Academy. — *The Observatory*, No. 498.

INTERNAL STRUCTURE OF THE EARTH AND MOON.— (CONCLUSIONS).— 1. It has been shown that the whole mass of the earth must have the hydrostatic form to a considerable degree of accuracy, owing to plasticity. This last, however, must act slowly in comparison with the rate of geological upheaval, as otherwise the continents could not exist.

2. The only possible distribution of density found is that given by Wiechert's hypothesis.

3. The adjustments may be either continuous or discontinuous. In the latter case some of them may correspond to times of great plutonic activity, as, perhaps, the Ordovician period.

4. Various hypotheses as to the structure of the moon have explained the largeness of its ellipticities by supposing it to have solidified when its period of revolution was about six of our present days; while the difference between the observed and theoretical values, if confirmed, has been explained by a possible considerable libration at the time of solidification.

5. The fact that the moon always turns the same face towards the earth has been shown to be not necessarily due to internal tidal friction, as in the absence of this the amplitude of the free libration in longitude would only increase with extreme slowness. If, therefore, this amplitude had been reduced to a small amount before solidification, tidal friction would not be required in order to keep it small.— HAROLD JEFFREYS in *Memoirs R.A.S.*, Vol. LX., Part 6.

THE SUN'S ORBIT.— We have known for a century that the sun is moving with reference to the average of the nearer stars and are now accustomed to speak of the "Sun's Way," or point toward which it is moving, as being between the star groups of Hercules and Lyra, probably within 10° or less of Vega (α Lyra). Whether it is moving in a straight line or in an arc of an enormous circle, or some other curve, it has been impossible to determine; although Alcyone, and later Canopus, have, on wholly insufficient grounds, been assigned the place of "central sun." Recently Professor Oppenheim, of Vienna, employing harmonic analysis upon the apparent motions (proper and radial) of 233 helium stars (Class B), with an approximation in regard to their parallaxes, has obtained some results which in his judgment seem to indicate the reality of motion, not only of the sun but of the stars, around one ideal centre. The sun as viewed from this centre appears in R.A. 203° 55′, Decl. − 34° 09′. The corresponding apex of the solar motion is at R.A. 266°, Decl. + 34° 37′. The discussion of the results is given in the *Astronomische Nachrichten*, No. 4822.— *Popular Astronomy* for March, 1916.

ON THE ALBEDO OF THE PLANETS.— The most suitable definition of albedo for astronomical purposes appears to be that proposed by Bond in 1861, namely, the ratio of the whole amount of light reflected in all directions from a sphere illuminated by parallel rays to the amount of light incident on the sphere.

The albedo $A$ of any planet, according to this definition, is the product of two factors, one of which depends only on the size of the planet, its distances from the earth and sun, and its brightness at the full phase, while the other depends upon the way in which the brightness varies at different phases. The first factor, which may be called $p$, can be calculated from known data for all the planets. Its value depends mainly upon the material of the surface, being high if this is nearly white, and low if it is dark colored. The second factor, $q$, can be computed only when the planet is observable over a considerable range of phase, so

that the law of variation of its brightness with phase can be determined, and its values are known only for the moon and the planets of the terrestrial group. For Jupiter and the remoter planets, however, estimates can be made which are not likely to be much more than 15 per cent. in error. This factor depends mainly upon the *texture* of the planet's surface, being high if this is smooth, and low if it is rough and covered with irregularities whose shadows darken considerable areas at phases remote from the full.

The relative brightness of the sun and stars, as seen from the earth, has been determined with surprising accuracy. The sun appears to be 123 thousand million times as bright as a standard first magnitude star.

The full moon is 8·7 times brighter than the first quarter, and 10·0 times brighter than the last quarter.

The ratio of sunlight to mean full moonlight 465,000,—with an uncertainty of fully 10 per cent.

Very's observations of the intensity of the earthshine indicate that the mean full earth, as seen from the moon, appears 40 times as bright as the mean full-moon, seen from the earth.

The intensity of sunlight from the zenith, according to H. H. Kimball, is 103,000 metre-candles. That of mean full moonlight, according to several observers, is 0·24 metre-candle. A standard candle, if of approximately the same color as the stars, would appear as bright as a star of the first magnitude if placed at a distance of 1·09 kilometres.

The albedo follows:—Moon, 0·073; Mercury, 0·069, 0·055; Venus, 0·59; Mars, 0·154; Jupiter, 0·56; Saturn, 0·63; Uranus, 0·63; Neptune, 0·73; The Earth, 0·45.

For Venus and the outer planets, which are generally supposed to be covered with clouds, the albedo is very near the value found by Abbot for terrestrial clouds (0·65). For Mars, Mercury and the moon the albedo is comparable with that of ordinary rocks, as it is also for three of the four asteroids.—Henry Norris Russell, in *Proceedings of the National Academy of Sciences*, for February, 1916. J. R. C.

## NOTES AND QUERIES

**Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries.**

### Query

Mr. Harper, in his extremely interesting and instructive address at Toronto, suggested that some, if not all, nebulæ being 20,000 or more light years distant, are apparently beyond the limits of the stellar system, and may be new universes in the process of making. I have always supposed that some of the stars which are seen through the veil of a nebula are beyond the nebula itself, but if Mr. Harper is right they must all be on this side. Can it be demonstrated definitely on which side they are?

The thought that some of these nebulæ are, perhaps, outside the stellar system will be a new one to many laymen. I, for one, had supposed all of them to be within our own universe, and to be systems, similar in kind to the solar system, in the making, the spirals being at a more advanced stage of development preparatory to casting off the parts which are to become planetary bodies. I wish Mr. Harper could have given us his idea of whether each star, like our sun, is the centre of a system which was evolved in the same way. I am taking it for granted that he believes in the nebular hypothesis.—H. W. B. (Toronto).

### Answer

It is a difficult problem to determine the distances of the stars, but it is very much more so in the case of the nebulæ, where we have no definite points for measurement. Consequently our knowledge of nebular distances is very limited.

In some cases, however, there seems to be a physical connection between certain stars and nebulæ and it is natural to assume that such nebulæ and related stars are at the same distances from us. Mention may be made of the Pleiades nebulæ, the Orion nebula, and the annular nebula in Lyra as examples of such a condition. In these cases if the parallaxes

of the stars can be obtained, then we can consider the nebulæ at the same distances.

The problem has been attacked in another way. Counts have been made of the stars in the neighborhood of an extended nebula, and the real distribution curve obtained. The numbers of stars of various magnitudes obtained from the B.D. catalogue for the same region have also been plotted. On the principle that the stars at the same distance as the nebula itself must follow the general distribution law, a certain magnitude is selected, the known mean distance of which is supposed to represent the distance of the nebula. (See Anderson's result for the North America nebula, *Astrophysical Journal*, Vol. XXXVIII., p. 275).

The gaseous nebulæ found in or near to the plane of the Milky Way do not differ markedly from the stars in either proper motion or radial velocity and it has come to be regarded as probable that the most of the gaseous nebulæ belong to our stellar system. Campbell's recent solution for the motion of the solar system through space, based on the velocities he has determined for the gaseous planetaries, in which a result was obtained in complete agreement with that obtained from 1073 stars, is in full support of this view.

The spiral nebulæ on the other hand have velocities of an extremely high order — some as high as 1000 km. per sec. Some of them, then, should show sensible proper motion unless they are inconceivably remote. They do not, and knowledge of these facts has strengthened the notion, previously held, that they are independent and isolated universes.

The solution for the motion of the solar system in space, based on the velocities of the spiral nebulæ and published in the last issue of the JOURNAL, wherein a result is arrived at which is at variance with that given by the stars, tends to strengthen the conception of the spirals as independent galaxies. Owing to the limited number of these velocities this result, however, ought to be accepted with reserve. W. E. HARPER.

## A MADE-IN-TORONTO AURORA

The present winter, as experienced in Toronto, has had several peculiar features. The month of January was exceptionally mild and it was not until we were well into February that the winter with its snow and cold appeared really to begin. In various quarters one hears the remark that our seasons are surely changing, that they appear two weeks or more later than a generation ago. I hope to publish before long in the JOURNAL a comprehensive article dealing with this subject.

The most remarkable storm of the season occurred on March 6. In the afternoon a blizzard from the east set in, and during the evening it reached a velocity of nearly fifty miles an hour. As the present writer was walking home at about 6.20, in the midst of the driving snow, a very bright flash was seen. At first one could hardly believe that it was lightning, but in a few seconds loud thunder was heard thus verifying its nature. Other flashes, accompanied with thunder, were observed during the evening. At about 7 p.m. the snow changed to sleet which somewhat later became rain.

On looking out of the window at 10 o'clock strange greenish flashes were observed shooting up from the horizon. These were to be seen in almost every quarter and at first were confidently recognized as auroral streamers. Indeed, a pocket spectroscope seemed to confirm this as it revealed some bright green lines, though at times they were strangely intense. At last, however, the manner in which some houses on a near by street were illuminated threw suspicion on the supposition that we were beholding an auroral display, and soon the nature of the phenomenon was revealed. The rain as it fell froze upon the overhead wires of the electric street railway and when the contact of the trolley with the wire was broken there was a brilliant green flash due to volatilized particles of copper. The result was a remarkably good imitation of auroral streamers. That others were surprised at the strange illumination was shown by telephone calls during the evening and inquiries next day.

## LOWELL OBSERVATION CIRCULARS

Recently Director Lowell has begun the publication of circulars reporting observations made at the Lowell Observatory. The first three refer to Mars at its present opposition, and are as follows :—

*March 8, 1916.*—The Martian canals in the region Aeria, from 40° north latitude to 6° south latitude, the Euphrates, Phison and others, at present observed near the centre of the disc, have darkened appreciably since the last presentation five weeks ago, showing the quickening effect from the north polar melting.

*March 9.*—The frost on Hellas, the mid-latitude of which is 45°, where the South Polar Cap is now in process of forming, diminished strikingly between the evenings of March 7th and 8th. The season in the northern hemisphere of Mars now corresponds to November 26th on the earth.

*March 14.*—Canals in the Mare Erythraeum have faded out since its last presentation. The Mare is now a light chocolate tint in contrast to blue-green markings elsewhere. Martian Season in southern hemisphere corresponds to November 27th.

To those who have sufficient telescopic power to observe the details on the surface of Mars these circulars will prove of great interest.

C. A. C.